Uncertainty about Future Climates

Making Sense of Climate Change and Policy

EES 3310/5310

Global Climate Change

Jonathan Gilligan

Class #20: Friday, February 21 2020

What is the Scientific Consensus?

What is the Scientific Consensus?

- Is there a consensus?
- If there is, should we trust it?

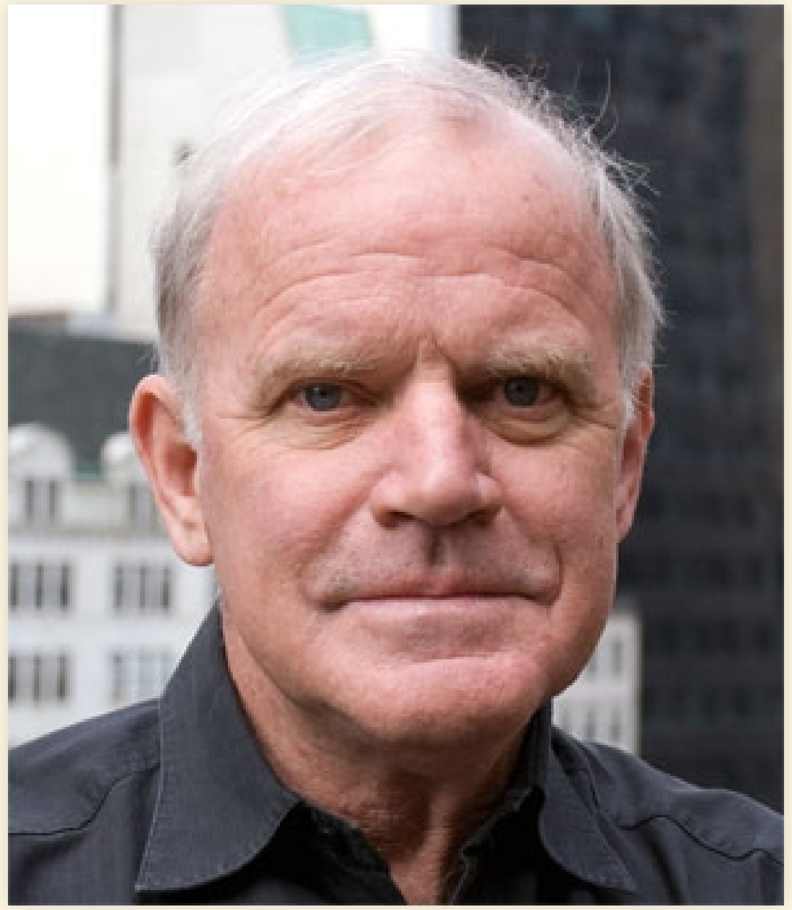
What is the Scientific Consensus?

- Is it important whether most scientists agree or not?
- What if some scientists disagree?
- Do most scientists agree?
  - Careful reviews of scientific literature find 95% of scientists publishing about climate change believe planet is warming because of human activity.

Dissident Scientists

Peter Duesberg

- Famous biology professor
- Member National Academy of Science
- Major discovery of cancer-causing virus
- Claims that HIV virus does not cause AIDS



Kary Mullis

- Nobel Prize in medicine/biology
- Invented PCR for analyzing DNA
- Endorses Duesberg’s theory of AIDS

Meaning of Consensus

- Does scientific consensus mean we can be 100% certain that people are warming the planet?
- What about the future impacts of climate change?

What Gets in the Way of Policy?

What Gets in the Way of Policy?

- Politicians don’t understand science?
- Public doesn’t understand science?
- Scientists don’t understand politics?

Issues for Policy

- What do scientists agree on?
- Should policy focus on limits to CO_2 or ΔT?
- Should policy wait for better scientific certainty?
- Uncertainty:
  - How much warming is “dangerous”?
  - How much CO_2 would produce dangerous warming?
  - Are there tipping points?
  - If so, where are they?
- Addressing uncertainty:
  - Precautionary principle
    - *Better safe than sorry*
  - No regrets policy
    - *Worth doing even if global warming turns out to be not so bad.*

1979 Report

**Carbon Dioxide and Climate:
A Scientific Assessment**

The conclusions of this brief but intense investigation may be comforting to scientists but disturbing to policymakers. If carbon dioxide continues to increase, the study group finds no reason to doubt that climate changes will result and no reason to believe that these changes will be negligible. … A wait-and-see policy may mean waiting until it is too late.

National Research Council, *Carbon Dioxide and Climate: A Scientific Assessment* (Nat'l. Academy Press, 1979)

Pielke and Nordhaus

Pielke and Nordhaus

Pielke:

Although some scientists believe that there may be "tipping points" … no one knows if or when there might be a threshold effect.

Nordhaus:

Humans are in effect spinning the roulette wheel when we inject CO_2 *and other gases into the atmosphere. The balls may land in the favorable black pockets or in the unfavorable red pockets, or possibly in the dangerous zero or double-zero pockets.*

Principles of Tipping Points

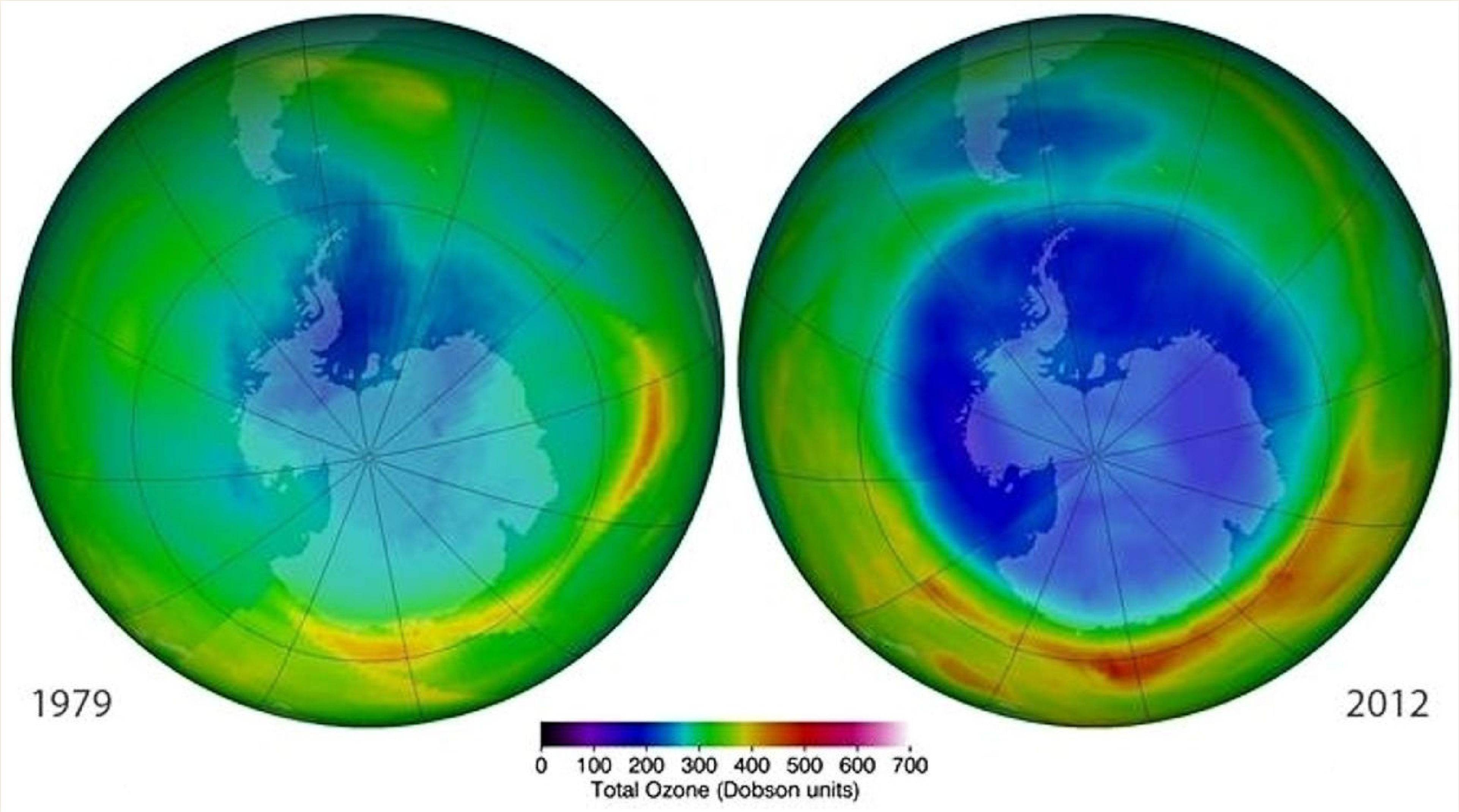
- Ordinary positive feedbacks amplify changes
  (hot → hotter, cold → colder).
  - Small positive feedbacks amplify but the *system remains stable*.
- If positive feedbacks are too strong they become *self-perpetuating*.
  - Secondary forcing from feedback creates *unstoppable change*.
- If feedback *strengthens with warming*:
  - Tipping point: feedback becomes strong enough
    to continue warming independent of external forcing.
- **Not all positive feedbacks have tipping points.**
- **Hard to predict** when a positive feedback might go from *amplifying* to *runaway* (tipping point).

Stratospheric Ozone

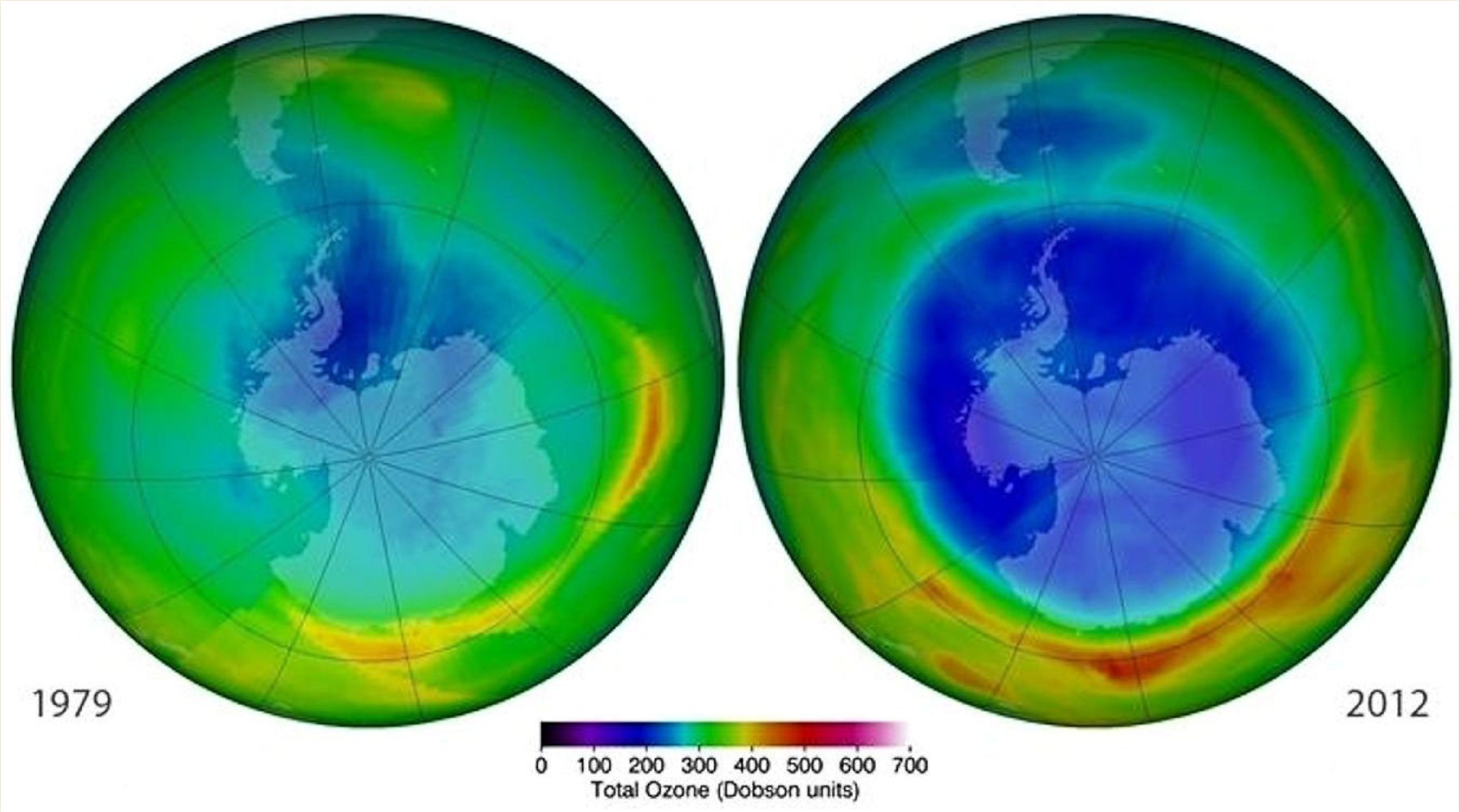
- Ozone is a naturally occurring molecule in the stratosphere
  - From 15–35 km altitude
- Blocks harmful ultraviolet (extreme shortwave) radiation
  - Disrupts DNA and proteins in the lens of the eye
  - Causes skin cancer
  - Causes blindness from cataracts
- Scientists have measured ozone from the ground since the 1920s
  - Useful for understanding winds and weather

Stratospheric Ozone Depletion

- 1974: Scientific prediction:
  - Chlorofluorocarbon chemicals will destroy ozone
  - Scientists believed ozone destruction would be gradual
- September 1980: Scientists in Antarctica see ozone go to zero in a matter of days
- 1985: Announcement: Discovery of a giant hole in the ozone layer over Antarctica every spring
- Tipping point:
  - Stratospheric chlorine < 2 parts per billion: No ozone hole
  - Stratospheric chlorine > 2 parts per billion: Ozone hole appears

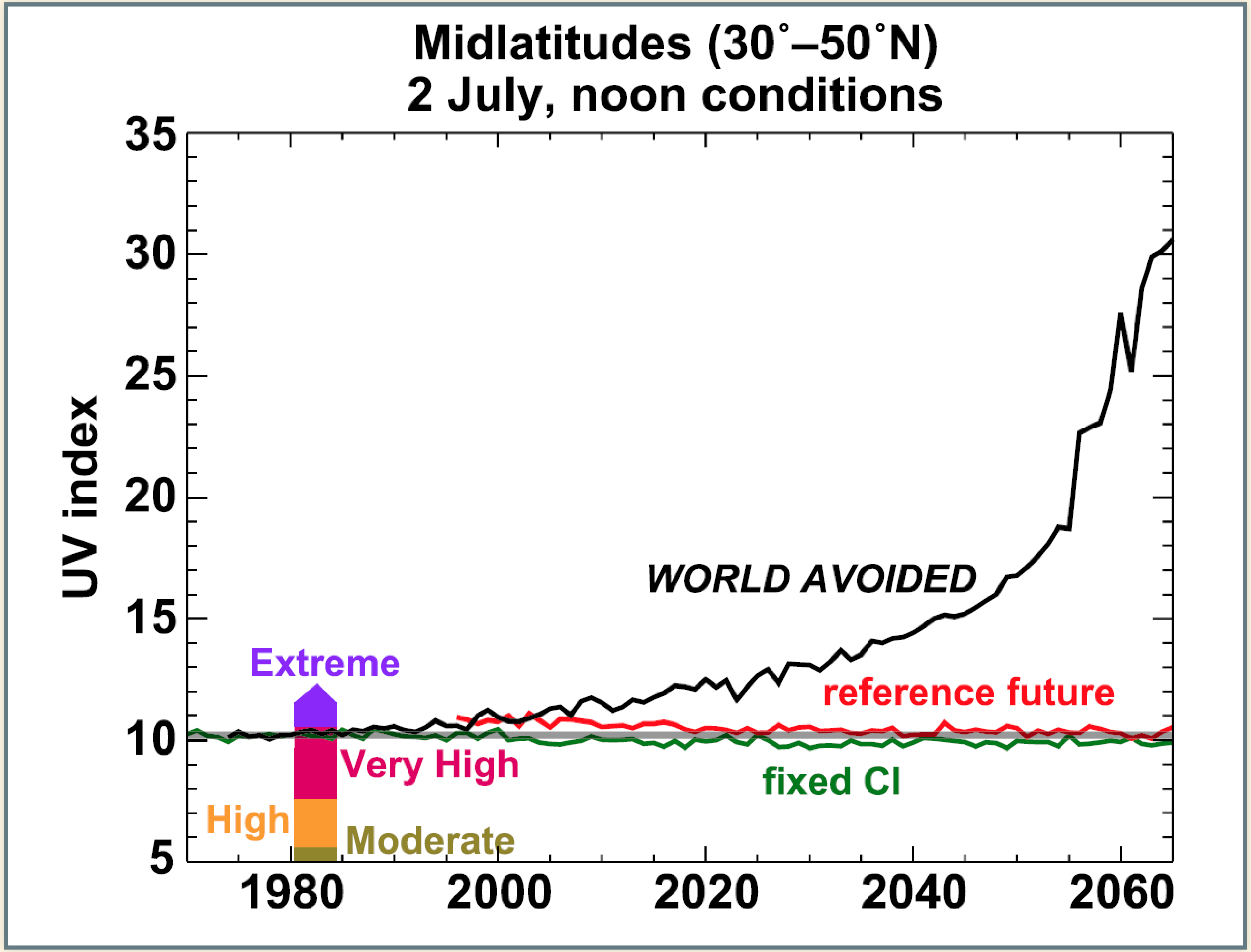


Ozone Policy



- 1970s: Significant scientific uncertainty
- Decision to take action without waiting for certainty
- Discovery of hole: tipping point
- Flexible policy (renegotiate details every two years)

Success: Avoided Futures

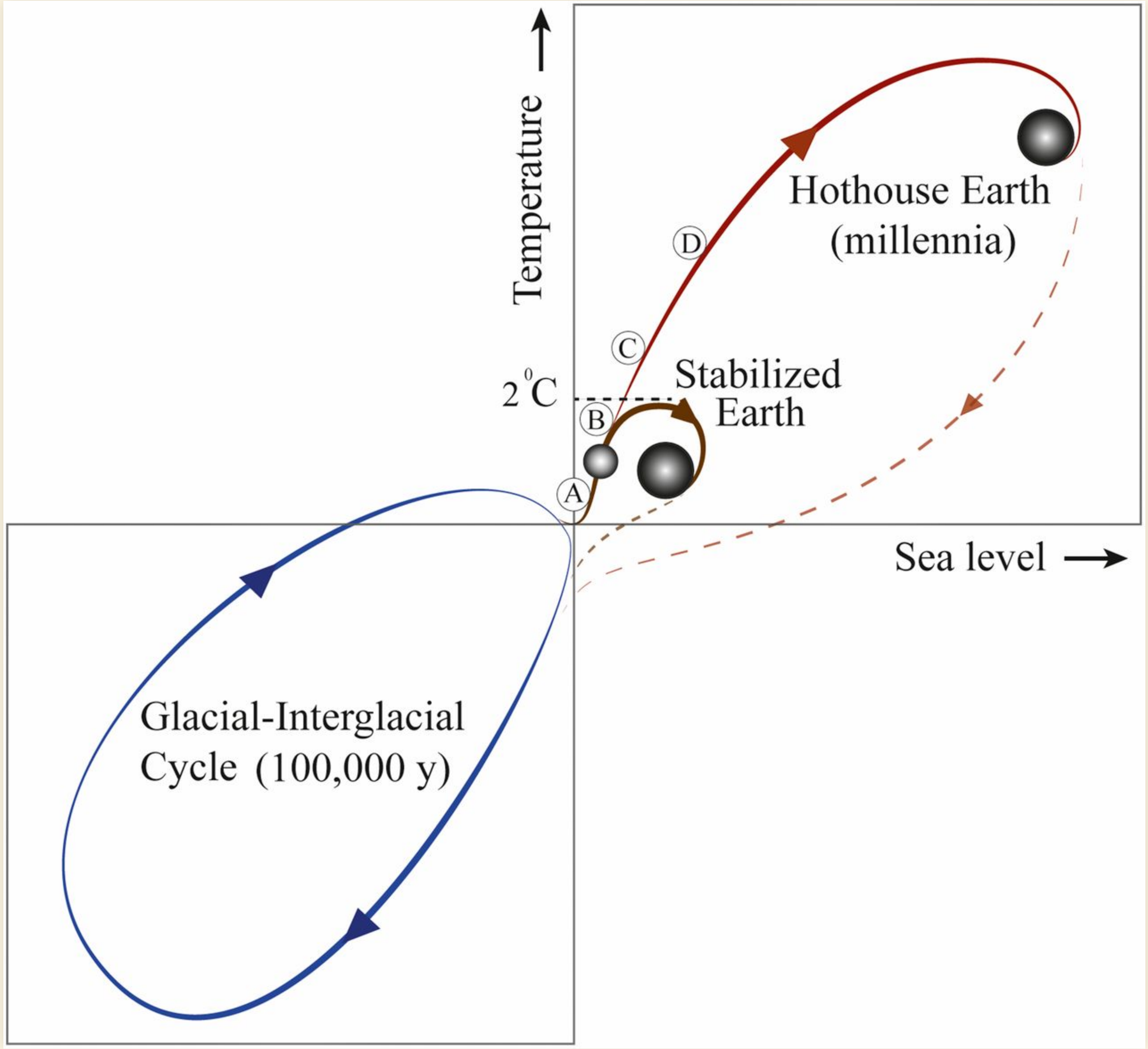


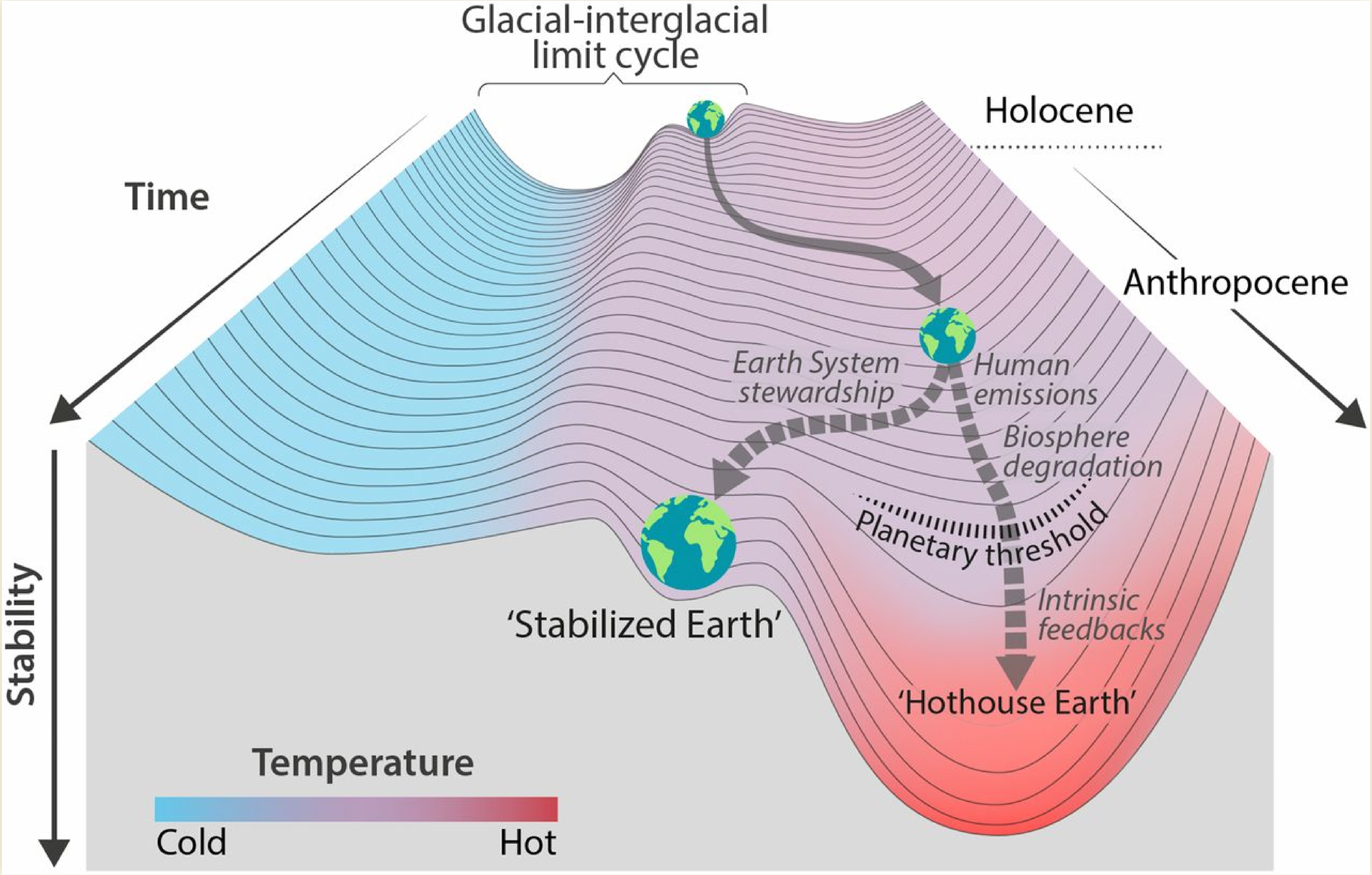
Important Note:

- The ozone hole is completely different from global warming
- Caused by chemical reactions with chlorine atoms
- However:
  - CFC chemicals that destroy ozone are also powerful greenhouse gases
  - Ozone depletion is temperature-sensitive
    - Hole over Antarctica because of very cold stratosphere (much colder than arctic)
    - Global warming cools stratosphere
    - If we had not stopped production of CFC chemicals An ozone hole might have started over arctic too.

Climate Tipping Points?

- *Climate Casino*: No big danger of fast tipping points if warming stays less than 3°C
- Recent research: West Antarctic Ice Sheet may have already crossed irreversible tipping point.
- New research suggests that global tipping points could occur as low as 2°C





W. Steffen *et al.*, PNAS 115, **8252** (2018). doi: 10.1073/pnas.1810141115

Recent Scientific Paper

Comment

Climate tipping points — too risky to bet against

Timothy M. Lenton, Johan Rockström, Owen Gaffney, Stefan Rahmstorf, Katherine Richardson, Will Steffen & Hans Joachim Schellnhuber

The growing threat of abrupt and irreversible climate changes must compel political and economic action on emissions.

Politicians, economists and even some natural scientists have tended to assume that tipping points[1] in the Earth system — such as the loss of the Amazon rainforest or the West Antarctic ice sheet — are of low probability and little understood. Yet evidence is mounting that these events could be more likely than was thought, have high impacts and are interconnected across different biophysical systems, potentially committing the world to long-term irreversible changes.

Here we summarize evidence on the threat of exceeding tipping points, identify knowledge gaps and suggest how these should be plugged. We explore the effects of such large-scale changes, how quickly they might unfold and whether we still have any control over them.

In our view, the consideration of tipping points helps to define that we are in a climate emergency and strengthens this year's chorus of calls for urgent climate action — from schoolchildren to scientists, cities and countries.

The Intergovernmental Panel on Climate Change (IPCC) introduced the idea of tipping points two decades ago. At that time, these 'large-scale discontinuities' in the climate system were considered likely only if global warming exceeded 5 °C above pre-industrial levels. Information summarized in the two most recent IPCC Special Reports (published in 2018 and in September this year)[2,3] suggests that tipping points could be exceeded even between 1 and 2 °C of warming (see 'Too close for comfort').

If current national pledges to reduce greenhouse-gas emissions are implemented — and that's a big 'if' — they are likely to result in at least 3 °C of global warming. This is despite the goal of the 2015 Paris agreement to limit warming to well below 2 °C. Some economists, assuming that climate tipping points are of very low probability (even if they would be catastrophic), have suggested that 3 °C warming is optimal from a cost–benefit perspective. However, if tipping points are looking more likely, then the 'optimal policy' recommendation of simple cost–benefit climate-economy models[4] aligns with those of the recent IPCC report[2]. In other words, warming must be limited to 1.5 °C. This requires an emergency response.

Ice collapse

We think that several cryosphere tipping points are dangerously close, but mitigating greenhouse-gas emissions could still slow down the inevitable accumulation of impacts and help us to adapt.

Research in the past decade has shown that the Amundsen Sea embayment of West Antarctica might have passed a tipping point[3]: the 'grounding line' where ice, ocean and bedrock meet is retreating irreversibly. A model study shows[5] that when this sector collapses, it could destabilize the rest of the West Antarctic ice sheet like toppling dominoes — leading to about 3 metres of sea-level rise on a timescale of centuries to millennia. Palaeo-evidence shows that such widespread collapse of the West Antarctic ice sheet has occurred repeatedly in the past.

The latest data show that part of the East Antarctic ice sheet — the Wilkes Basin — might be similarly unstable[3]. Modelling work suggests that it could add another 3–4 m to sea level on timescales beyond a century.

The Greenland ice sheet is melting at an accelerating rate[3]. It could add a further 7 m to sea level over thousands of years if it passes a particular threshold. Beyond that, as the elevation of the ice sheet lowers, it melts further, exposing the surface to ever-warmer air. Models suggest that the Greenland ice sheet could be doomed at 1.5 °C of warming[3], which could happen as soon as 2030.

Thus, we might already have committed future generations to living with sea-level rises of around 10 m over thousands of years[3]. But that timescale is still under our control. The rate of melting depends on the magnitude of warming above the tipping point. At 1.5 °C, it could take 10,000 years to unfold[3]; above 2 °C it could take less than 1,000 years[6].

An aeroplane flies over a glacier in the Wrangell St Elias National Park in Alaska.

FRANS LANTING/NAT. GEO. IMAGE COLLECTION

Researchers need more observational data to establish whether ice sheets are reaching a tipping point, and require better models constrained by past and present data to resolve how soon and how fast the ice sheets could collapse.

Whatever those data show, action must be taken to slow sea-level rise. This will aid adaptation, including the eventual resettling of large, low-lying population centres.

A further key impetus to limit warming to 1.5 °C is that other tipping points could be triggered at low levels of global warming. The latest IPCC models projected a cluster of abrupt shifts[7] between 1.5 °C and 2 °C, several of which involve sea ice. This ice is already shrinking rapidly in the Arctic, indicating that, at 2 °C of warming, the region has a 10–35% chance[3] of becoming largely ice-free in summer.

> "The clearest emergency would be if we were approaching a global cascade of tipping points."

Biosphere boundaries

Climate change and other human activities risk triggering biosphere tipping points across a range of ecosystems and scales (see 'Raising the alarm').

Ocean heatwaves have led to mass coral bleaching and to the loss of half of the shallow-water corals on Australia's Great Barrier Reef. A staggering 99% of tropical corals are projected[2] to be lost if global average temperature rises by 2 °C, owing to interactions between warming, ocean acidification and pollution. This would represent a profound loss of marine biodiversity and human livelihoods.

As well as undermining our life-support system, biosphere tipping points can trigger abrupt carbon release back to the atmosphere. This can amplify climate change and reduce remaining emission budgets.

Deforestation and climate change are destabilizing the Amazon — the world's largest rainforest, which is home to one in ten known species. Estimates of where an Amazon tipping point could lie range from 40% deforestation to just 20% forest-cover loss[8]. About 17% has been lost since 1970. The rate of deforestation varies with changes in policy. Finding the tipping point requires models that include deforestation and climate change as interacting drivers, and that incorporate fire and climate feedbacks as interacting tipping mechanisms across scales.

With the Arctic warming at least twice as quickly as the global average, the boreal forest in the subarctic is increasingly vulnerable. Already, warming has triggered large-scale insect disturbances and an increase

T. Lenton *et al.*, Nature **575**, 592 (2019).

Goals for Climate Policy

Goals for Climate Policy

- Limit temperature rise?
- Limit greenhouse gas concentrations?
- Focus only on CO_2?
- Focus broadly on all kinds of climate change (natural and human)?
- What do Pielke and Nordhaus say about these questions?
- What do you think?
- Pielke:

> *"A narrow focus on carbon dioxide is double-edged: it gives priority to a very important aspect …, but it can obscure the fact that … climate change involves so much more."*

Scientific Uncertainty

- How does scientific uncertainty affect policy?
- Should we wait for more certainty before acting?
- What do Pielke and Nordhaus say?
- What do you think?

- Nordhaus:

  “A sensible policy would pay an insurance premium to avoid playing the roulette wheel.”

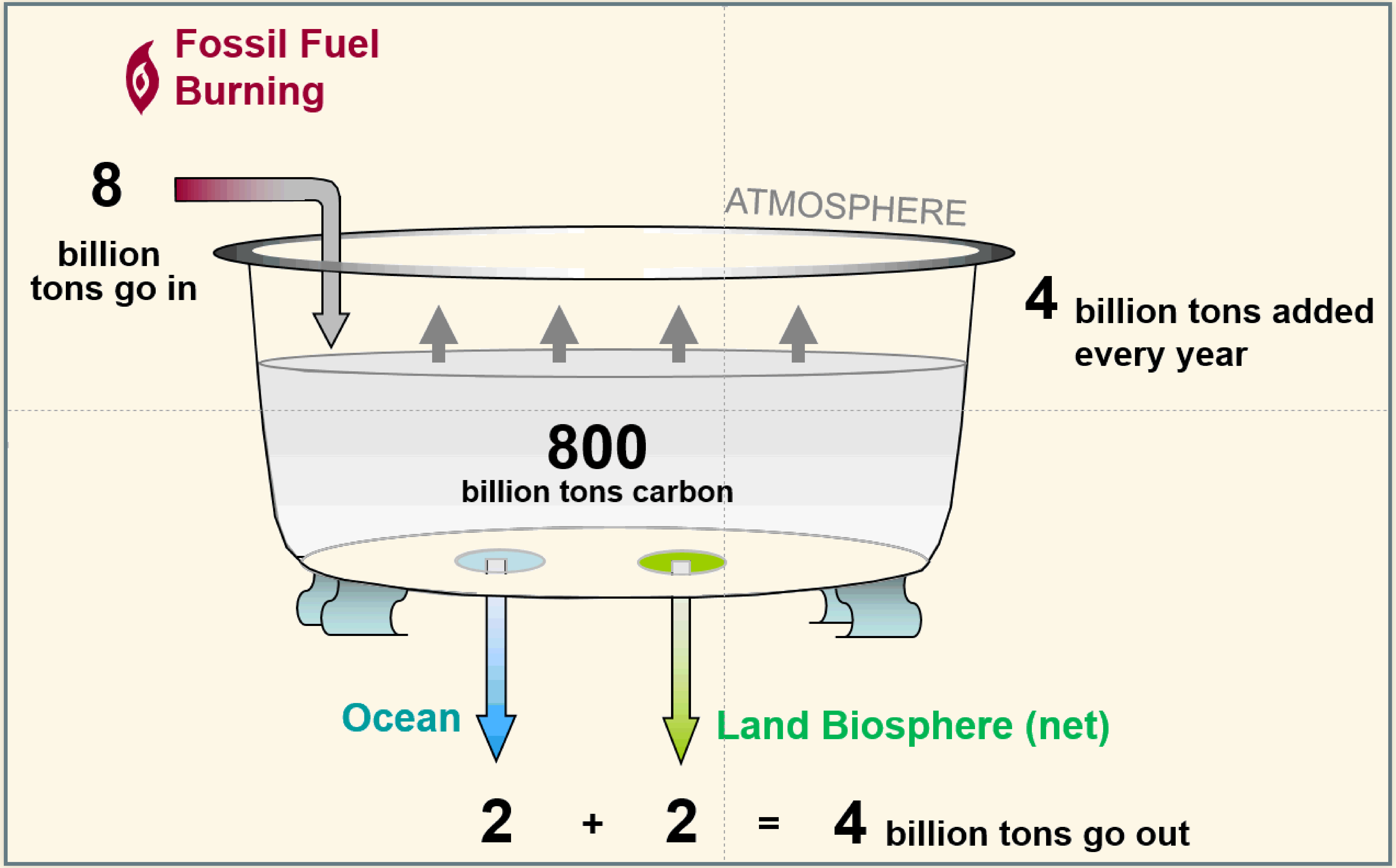
  “The cost of delaying action for 50 years … is [estimated] as $6.5 trillion.”

- Pielke:

  “Policy makers routinely make decisions … with a similar (or even less well-developed) state of understanding.”

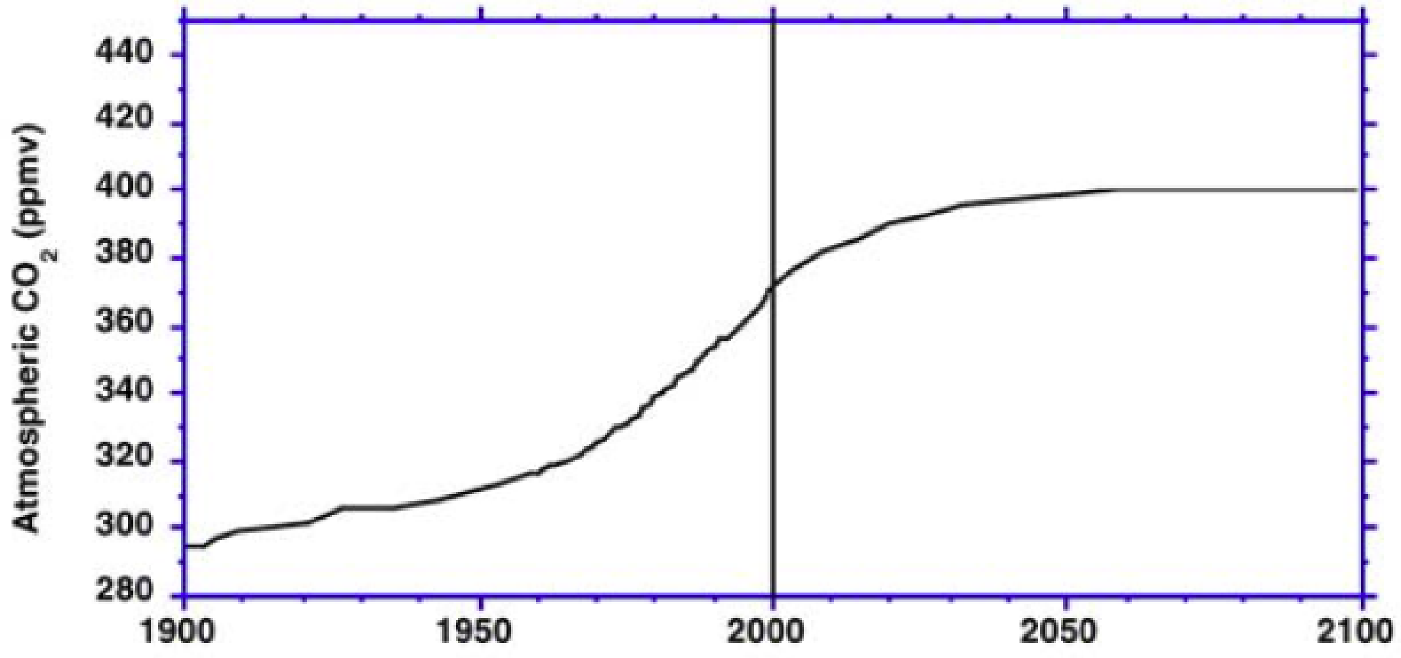
Bathtub model

Bathtub model

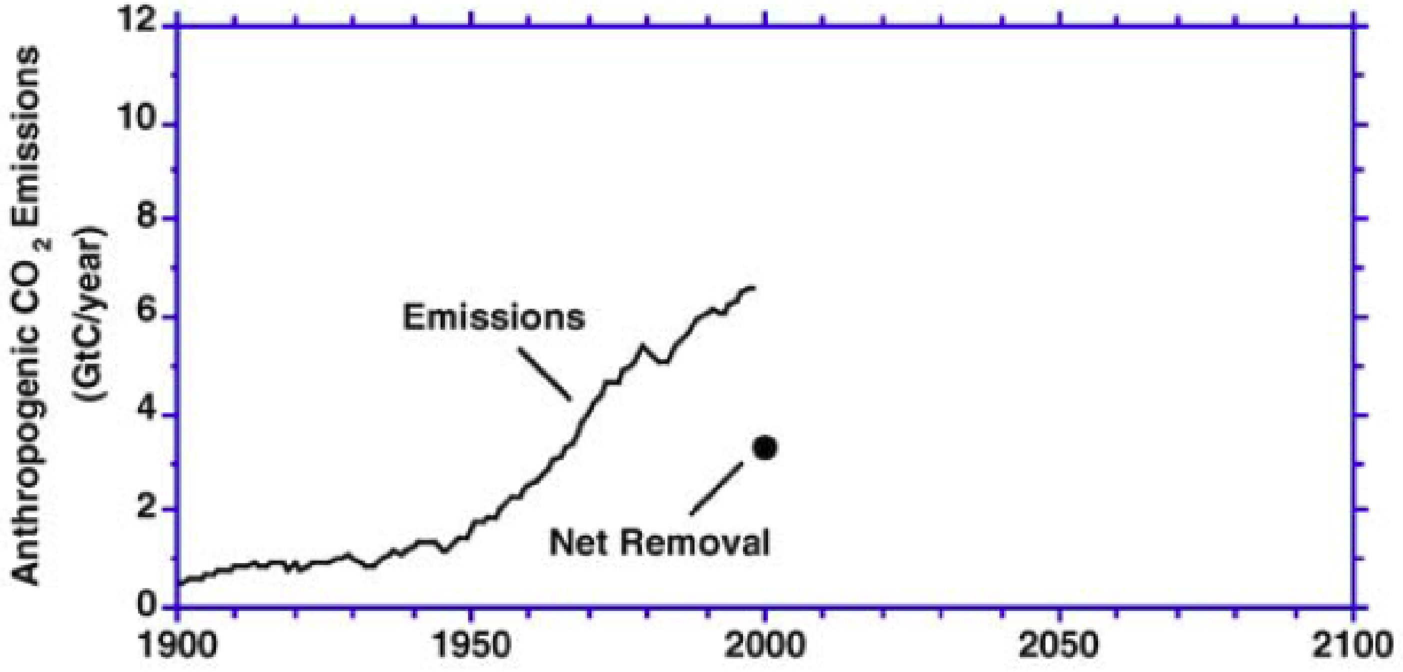


Bathtub model

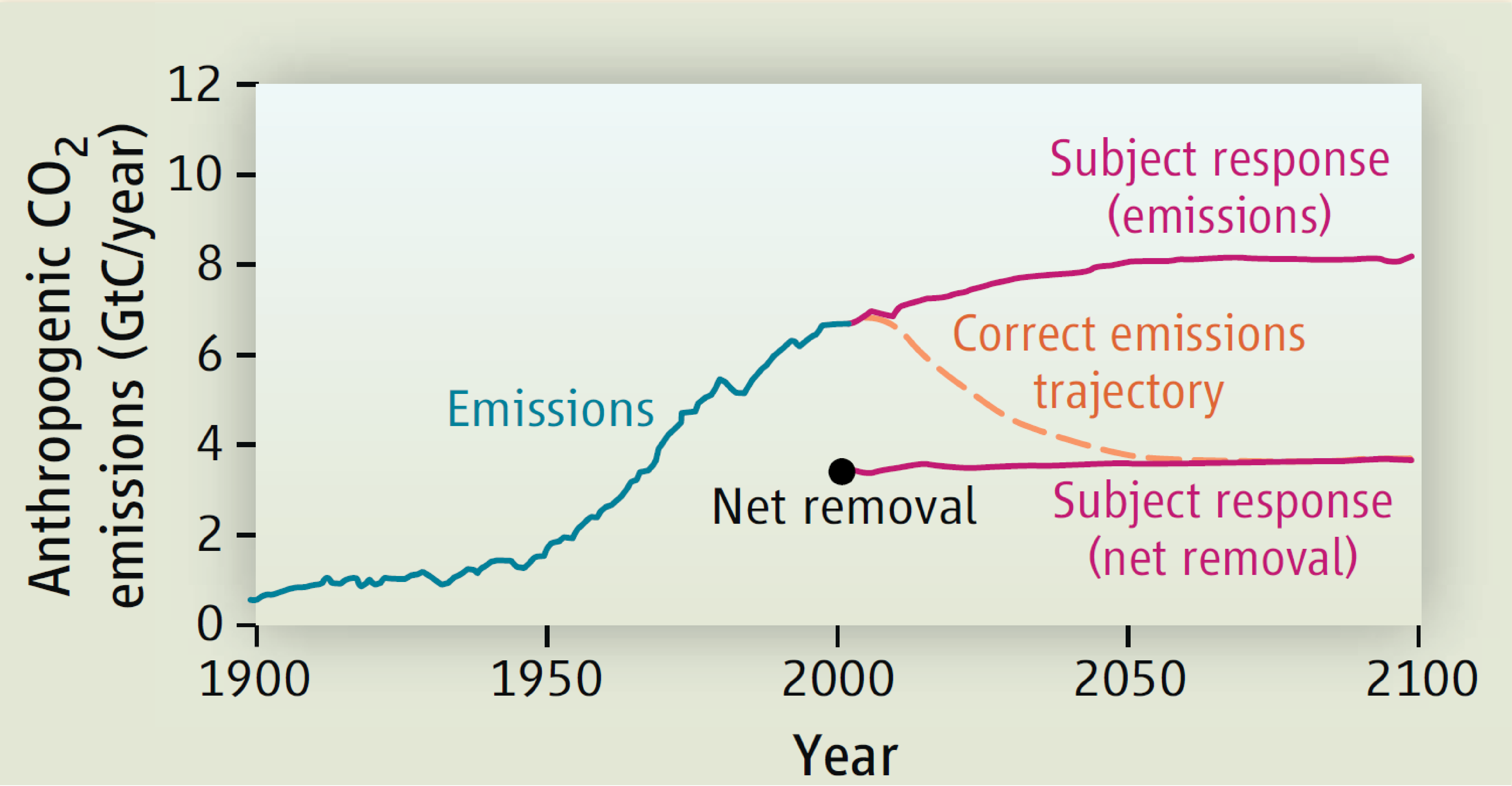
Now consider a scenario in which the concentration of CO_2 in the atmosphere gradually rises to 400 ppm, about 8% higher than the level today, then stabilizes by the year 2100, as shown here:



1. The graph below shows anthropogenic CO_2 emissions from 1900-2000, and current net removal of CO_2 from the atmosphere by natural processes. Sketch:
   a. Your estimate of likely future net CO_2 removal, given the scenario above.
   b. Your estimate of likely future anthropogenic CO_2 emissions, given the scenario above.



Bathtub model



J.D. Sterman, Science **322**, 532 (2008).

- 212 MIT MBA and graduate students.
- 60% majored in science or engineering